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Original Contribution

Zoonotic Disease Risk and the Bushmeat Trade: Assessing Awareness Among Hunters and Traders in Sierra Leone

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Abstract: The bushmeat industry has been a topic of increasing importance among both conservationists and public health officials for its influence on zoonotic disease transmission and animal conservation. While the association between infectious diseases and the bushmeat trade is well established in the research community, risk perception among bushmeat hunters and traders has not been well characterized. I conducted surveys of 123 bushmeat hunters and traders in rural Sierra Leone to investigate hunting practices and awareness of zoonotic disease risk associated with the bushmeat trade. Twenty-four percent of bushmeat hunters and traders reported knowledge of disease transmission from animals to humans. Formal education did not significantly affect awareness of zoonotic disease transmission. Individuals who engaged exclusively in preparation and trading of bushmeat were more likely to accidentally cut themselves compared to those who primarily engaged in bushmeat hunting ($P < 0.001$). In addition, women involved in the bushmeat trade were at greater risk of exposing themselves to potential zoonotic pathogens through accidental self-cutting compared to men ($P < 0.01$). This study collected preliminary information on risk perception among bushmeat hunters that could guide the creation of a future public health-based education program to minimize zoonotic disease transmission risk among vulnerable communities.

Keywords: zoonosis, bushmeat, public health

Introduction and Purpose

The bushmeat industry in West and Central Africa is of great concern for its influence on infectious disease transmission and animal conservation. Communities worldwide have implemented sustainable bushmeat hunting practices to fulfill vital protein needs. However, bushmeat hunting in West and Central Africa has risen unsustainably, threatening the future livelihoods of not only bushmeat species, but also the human communities that depend on bushmeat for nutrition (Fa et al. 2003, 2005). In addition to deforestation, disease, and climate change (among other threats), bushmeat hunting represents a serious pressure on the depletion of certain wildlife populations in West Africa. In a survey of bushmeat traded in the Cross-Sanaga Rivers region of Nigeria, Fa et al. (2006) estimated that over 900,000 kg of bushmeat was sold annually. Human population growth in West Africa has created greater demands for a variety of protein sources, especially bushmeat, when domesticated sources are unavailable (Bowen-Jones and Pendry 1999). From 1950 to 2000, the population in West Africa more than

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quadrupled, creating additional challenges for food security (Fuwape and Onyekwelu 2010).

In addition to population growth, West Africa has experienced significant landscape changes due to agricultural expansion (with subsequent human migration), cocoa harvesting, logging, and mining, which threaten existing biodiversity (Norris et al. 2010). Increased interface between human and animal populations via deforestation and road construction facilitate accessibility to bushmeat hunting (Wolfe et al. 2005a). Guns and cable snares have replaced traditional hunting techniques (e.g., nets, bow and arrow, and machete), enabling hunters to catch a greater volume of meat per hunt (Bowen-Jones and Pendry 1999; Bowen-Jones et al. 2003; Nasi et al. 2008). The increased supply of meat per hunting venture allows for commercial selling in addition to any subsistence consumption. In addition, civil conflict, which can result in an increase in internally displaced persons reliant on forest resources, has had serious implications for driving up bushmeat demand (Draulans and Van Krunkelsven 2002). Civil wars in the Democratic Republic of Congo have demonstrated regional effects of overharvesting of large mammalian species. For example, eastern lowland gorillas (*Gorilla gorilla graueri*) face increased predation threats as Congolese civilians are forced into forests for protection and are driven to hunting primates for food (Nasi et al. 2008; Yamagiwa 2003). This pattern may not hold true for all regions with a history of conflict and bushmeat consumption. In Sierra Leone, studies of the effects of civil conflict in protected parks, such as Gola Forest, have not observed as strong of a link between conflict and increased bushmeat hunting for most protected species (Lindsell et al. 2011). Finally, urban demand for bushmeat can result in overharvesting, and may suggest that bushmeat serves a role in cultural maintenance in certain communities. Surveys of the effect of wealth and price found a positive correlation between household wealth and bushmeat demand in Gabon, suggesting that bushmeat consumption may not always be linked to inability to access more expensive protein resources (Wilkie et al. 2005) However, the impact of cultural preferences on bushmeat demand is not well defined or consistent across regions.

These patterns are concerning for the future of many species. In nature reserves in Ghana, Brashares et al. (2004) determined that bushmeat served as an important protein substitute when supplies of the primary protein source, fish, were reduced. Thus, depletion of bushmeat species could result in loss of alternative protein options. Fa et al. (2003) determined that given the current rate of hunting, the amount of wild protein available will significantly decrease by 2050, and agricultural meat sources will not be enough to fill the void. This is of great concern to poor and rural communities who do not have realistic alternatives for obtaining protein.

In addition to having serious implications for wildlife conservation and depletion of protein sources, the increase in bushmeat hunting has alarming consequences for both animal and human health. Animal and human health are interdependent, with pathogens crossing over between species, occasionally resulting in disease. Approximately, 75% of human emerging infectious diseases worldwide are zoonotic in origin (Taylor et al. 2001; Karesh and Noble 2009). Increased exposure to wildlife habitats, blood, fur, and saliva increases the probability of disease transmission between animals and humans (Weiss and McMichael 2004). Interactions between humans and animals through crop raiding, carcass handling, habitat sharing, and raising domesticated animals (which interface with both humans and wild animals) present opportunities for zoonotic disease transmission (Naughton-Treves et al. 1998; Weiss and McMichael 2004).

There are several demonstrative cases, especially in nonhuman primates, of emerging infectious diseases arising from bushmeat. Ebola and human T-lymphotropic viruses (HTLV) are among a variety of diseases that scientists believe transferred to humans from non-human primates (Leroy et al. 2004; Weiss and McMichael 2004; Wolfe et al. 2005b; Zheng et al. 2010). Three outbreaks of the Ebola virus in the Democratic Republic of Congo from 1976–1979 involved victims who were reported to have handled dead gorilla or chimpanzee carcasses or to have had physical contact with people who touched the animals (Leroy et al. 2004). One notable case of viral transmission between humans and non-human primates is the Human Immunodeficiency Virus (HIV). HIV-1 and HIV-2 are believed to have evolved from strains of Simian Immunodeficiency Virus (SIV) (Hahn et al. 2000; Lemey et al. 2003; Daszak et al. 2007). There is evidence suggesting that SIV crossed over to humans by blood contact when hunters had an exposed open wound or injured themselves during the butchering of non-human primate meat (Hahn et al. 2000; Wolfe et al. 2004a, b; Karesh and Noble 2009).

The risk of zoonosis remains high, especially among women. While tracking, trapping, and slaying bushmeat game elevate the risk of exposure to zoonotic pathogens, the act of butchering presents the highest risk for transmission (Wolfe et al. 2005a). Butchering increases the opportunities for creating wounds, which can allow entry

of animal blood and bodily fluids. In a study on bushmeat hunting communities in rural Cameroon, Wolfe et al. (2004a, b) found that although women and men were equally likely to engage in the processes involved in bushmeat harvesting and consumption, women made up more than half of those who butchered the slain animals. Thus, women may represent a subgroup at elevated risk for zoonotic transmission.

In order to lower illegal bushmeat activity, several methods have been proposed, including strengthening local enforcement, developing alternative protein sources, promoting community stewardship of natural resources and fauna, and selective hunting (Hackel 1998; Bowen-Jones and Pendry 1999; Wilkie and Carpenter 1999; Marcus et al. 2004). However, in practice, none of these methods have proven successful. Currently, there is no large-scale program that utilizes public health education as a means of reducing zoonotic transmission risk and altering unsustainable hunting practices. Furthermore, only one study to date has surveyed communities' perceptions of disease risk associated with hunting. LeBreton et al. (2006) conducted a survey in southern Cameroon to assess hunting behaviors and attitudes toward contact with wildlife while simultaneously conducting an HIV education campaign. The survey found that although 74% of respondents reported to perceive a risk associated with wild animal blood and bodily fluids, only 4% of hunters and 2% of those who butchered reported that they took precautionary measures. In addition, the survey reported that individuals who obtained higher levels of education were more likely to consume and butcher bushmeat. However, LeBreton et al. (2006) reported that individuals who did not identify risk in handling bushmeat were 27% more likely to engage in butchering. It is important to note that LeBreton et al. (2006) did not survey these individuals on the underlying reason for associating risk with handling animal blood. Thus, there remains a possibility that perceived risk was due to cultural influence as opposed to awareness of zoonosis. In addition, the survey was conducted in concert with an HIV education campaign, and thus villagers' attitudes toward bushmeat and disease risk prior to an educational intervention could not be accurately assessed and compared. While Le Breton et al. (2006) suggested that a public health education campaign could be useful in increasing use of disease transmission risk reduction strategies among bushmeat hunters and butchers, an education campaign was not foreseen to be effective in reducing actual bushmeat harvest rates due to the relative unavailability of domestic protein sources.

The current study aims to assess awareness of zoonotic disease risk associated with bushmeat hunting prior to the implementation of an educational intervention. I aimed to establish a baseline of the perceptions of individuals engaged in the bushmeat trade on the possibility of animals transmitting diseases to humans. To do so, I conducted a survey of bushmeat hunters and butchers in the southern half of Sierra Leone. Sierra Leone endured civil conflict from 1991–2002 (CIA 2010). Although the country is rich in mineral resources, much of the population lives below the poverty line. Roughly half of the working age population engages in subsistence farming. Bushmeat hunting is a common practice in the country, which contains four non-hunting forest reserves and one national park. Sierra Leone also harbors several endangered species, including the Western Chimpanzee (*Pan troglodytes verus*) (IUCN 2010). Through the support of the Tacugama Chimpanzee Sanctuary based in Freetown, I surveyed hunters, butchers, and traders on their hunting and trading practices, awareness of zoonotic disease transmission, and use of wildlife in traditional medicine. I expected three trends to characterize hunting practices and awareness of zoonotic disease transmission associated with the bushmeat trade:

1. Decreased bushmeat hunting and trading activity among individuals who expressed awareness of animals transmitting diseases to humans.
2. Increased proportion of individuals who obtained some level of formal education among those who expressed awareness that animals could transmit diseases to humans.
3. Increased accidental self-cutting among individuals who traded bushmeat compared to individuals who only hunted. Trading bushmeat, in this study, was characterized by butchering, preparation, and selling of bushmeat. Furthermore, as women are more likely than men to engage exclusively in the trading of bushmeat, I expected to observe an overrepresentation of women among those who accidentally cut themselves. A high frequency of cutting oneself could represent a risk factor for transmission of bloodborne zoonotic pathogens.

To assess these predictions, I conducted structured interviews of 123 individuals who participated in bushmeat hunting and/or trading. I collected specific information regarding bushmeat hunting and trading activities, preferences, and perceptions of zoonotic disease transmission risks. The information collected was analyzed to address the predictions outlined above, and to gauge the appropriateness

Figure 1. Survey sites. *Shaded regions* represent nationally protected areas.

of a public health education campaign to reduce zoonotic transmission risks and influence hunting behavior.

Methods

In conjunction with Tacugama Chimpanzee Sanctuary, I conducted surveys of bushmeat hunters and traders in 37 sites in Sierra Leone from May–July 2010. Hunters were defined as individuals who reported killing wildlife using guns, traps, nets, chains, or dogs. Traders were defined as individuals who butchered bushmeat and sold or bartered the meat for profit or material goods. The interview sites were selected based on findings of bushmeat activity provided by preliminary reports from the Sierra Leone National Chimpanzee Census. These sites are located in the southern half of Sierra Leone, specifically in the Western Area Peninsula, Moyamba, Tonkolili, Bo, Kenema, and Kono districts (Fig. 1). Most sites are villages, with the exception of Wilberforce Market, Bo Town, Kenema, and Kono, which are larger market towns that served as regional centers of commerce and trading.

Recruitment of participants occurred primarily by requesting village chieftains to identify and assemble known hunters and traders. Tacugama staff administered the survey to all participants. Minimizing bias of participant responses was of great concern. Participants in the survey may have been uncomfortable in reporting the true extent of their bushmeat hunting and trading practices to Tacugama staff, who worked for a conservation-focused organization. Staff members, who were fluent in several tribal languages and had prior experience in community outreach work, explained the details of the survey to village chieftains. Village chieftains were explicitly told that no legal action would result from participating, and that responses were strictly for academic purposes only. Village chieftains were asked to identify individuals in their area who hunted (either actively or through trap setting) or traded and prepared bushmeat. Individuals were not excluded based on whether or not they hunted protected species or hunted in protected areas. After explaining the purpose of the survey, a Tacugama staff member performed the informed consent process individually with each participant in the participant's preferred language. To make participants feel less reluctant about being honest in their responses, Sanctuary

staff emphasized that their results would not receive disciplinary or legal action based on the results they provided. Surveys of the participants were based off of a questionnaire that was delivered orally by Tacugama staff, and responses were recorded and later transcribed. Languages used included English, Krio, Mende, Temne, Sherbro, Kono, and Kronko. One hundred and twenty-three hunters and traders participated in the survey.

The questionnaire, which received approval by the Duke University Institutional Review Board, was divided into three segments: demographics, hunting practices, and risk perception (Table 1). Most questions were restricted to a selection of possible answers. In addition to computing percentages of responses across participant groups, Chi square tests of independence were performed to analyze categorical data.

Table 1. Information Obtained from Questionnaires.

Demographic information
Age
Gender
Town or village of birth
Married (Y/N)
Number of children
Tribe
Languages spoken
Level of formal education attained (none/primary school/junior secondary school/senior secondary school/university or higher)
Religion practiced
Two most common work activities performed during the day
Hunting practices and preferences
Participation in bushmeat hunting (Y/N)
Participation in bushmeat sale or trade (Y/N)
Frequency of hunting bushmeat (at least once a week/1-2 times per month/1-2 times per year)
Reasons for hunting bushmeat (consumption only/sale or trade/cultural practice/special occasions and celebrations)
Method of hunting bushmeat (gun/wire snare/net and dog/chains)
Location of bushmeat sale or trade (in the participant's village/in nearby villages/in market towns)
Preferred bushmeat game (Y/N; if yes, list examples)
Animals that will not be hunted (Y/N; if yes, list example and provide reason)
Times of the year that participant will not engage in hunting (Y/N/if yes, list when and provide reason)
Awareness of zoonotic potential and risk factors
Awareness in whether or not animals could transmit diseases to humans (Y/N; if yes, provide examples)
If participant hunted, how often was he/she bitten by bushmeat animal (never/only once/very rarely/occasionally/often)
If participant butchered bushmeat game, how often did he/she cut himself/herself (never/only once/very rarely/occasionally/often)
Belief in wildlife's use as traditional medicine (Y/N; if yes, provide examples)

Results

Demographic Information

Of the 123 participants, 85% were male. The participants' ages ranged from 15 to 85 years. Seventy-four percent of all participants were married, and 70% reported having children. The average number of children per survey participant was 5.5. Twelve tribes were represented, with most individuals self-identifying themselves as part of the Mende (33%), Kono (27%), Temne (20%), and Sherbro (7%) tribes. Sixteen languages were spoken among participants, with Krio, Mende, Temne, and Kono being the most common among 86, 48, 36, and 28% of participants, respectively. Approximately, 32% of all participants identified as Christian while 67% identified as Muslims. The majority of participants (53%) had no formal education, while 27 and 10% stopped at primary school and junior secondary school, respectively. Nine individuals attended senior secondary school, and three individuals received university level education. Farming and hunting were reported as the two most common daytime activities, at 81 and 41%, respectively.

Hunting and Trading Practices

Of the 123 participants, 81% ($N = 101$) identified as hunters. Of these hunters, 97% ($N = 98$) reported hunting bushmeat at least once per week while the remaining three individuals hunted one to two times per month. As almost all of the hunters surveyed hunted at least once per week, the relationships between hunting frequency by education level, religion, and tribal group could not be discerned.

Thirty-two percent ($N = 33$) of hunters hunted for consumption only, while 68% ($N = 69$) hunted for both consumption and trade. Three individuals reported hunting bushmeat for cultural practice and use in celebrations. Seven individuals reported hunting bushmeat due to excessive cropraiding. Wire snares were the most commonly

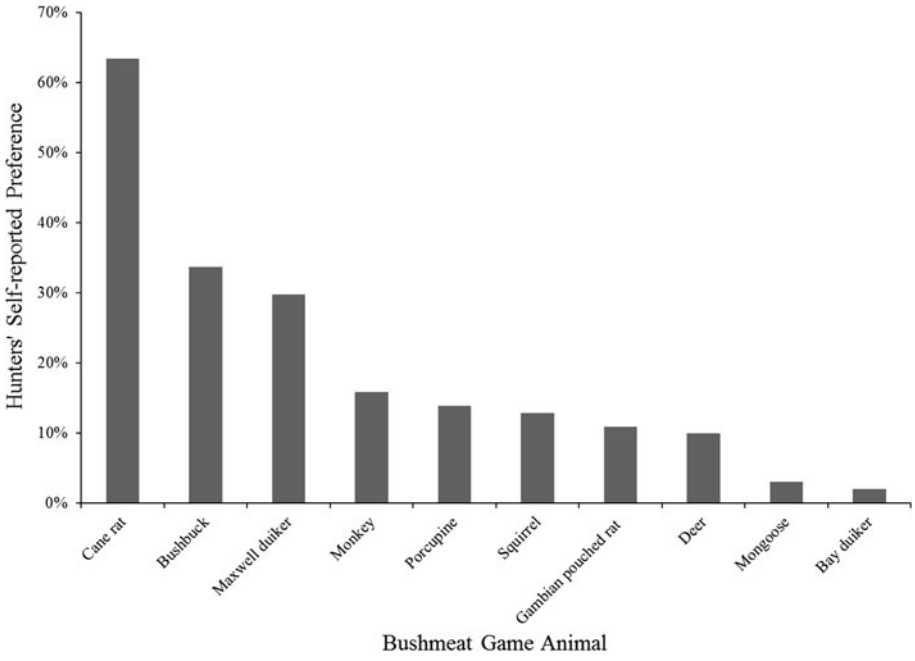

Figure 2. Top ten preferred bushmeat game animals among hunters (n = 101). Hunters were asked to list their three most preferred bushmeat game animals. The ten most frequently listed animals are represented.

used hunting method, with 75% of hunters (N = 76) reporting their regular use. Hunting by net and dog together was used by 35% of hunters (N = 35), and 3 hunters reported using chains. Gun use was not reported by any participant. The Greater Cane Rat (*Thryonomys swinderianus*), Maxwell's Duiker (*Philantomba maxwellii*), and Bushbuck (*Tragelaphus scriptus*) were the most commonly hunted bushmeat animals (Fig. 2). Sixteen percent of hunters (N = 16) reported monkey species as preferred bushmeat game. Chimpanzees were not reported as a preferred game animal. The water buffalo (*Syncerus caffer*), chimpanzee (*P. troglodytes verus*), and warthog (*Phacochoerus africanus*) were the most commonly listed non-preferred species. The most frequently given reasons for avoiding hunting these species were perceived danger of the hunt (30%) and religious restriction (13%). Only one individual cited the illegal nature of hunting a protected species as a reason to avoid a specific species (in this case, the Western Chimpanzee).

Of all survey participants, 17% (N = 21) engaged exclusively in trading and preparation of the bushmeat. Women constituted 86% (N = 18) of exclusive traders. Seventy-three percent of traders (N = 15) reported selling and/or bartering bushmeat within their own village, while 2 and 7 individuals reported also transporting the meat to nearby villages and larger market towns for commercial sale, respectively. Among individuals who farm as their primary daytime activity (N = 100), 77% hunted for both consumption and trade, compared to 28% who hunted for consumption only. There was no difference in level of participation in commercial bushmeat hunting among those who did and did not receive formal education (χ^2 = 0.0105, P = 0.9185).

Awareness of Zoonotic Disease Risk and Risk Factors for Crossover

Among all hunters (N = 101) and bushmeat traders (N = 21), 24% were aware of the possibility of disease transmission from animals to humans. Of survey participants with no formal education (N = 66), 17% were aware of zoonosis, whereas 32% of participants who obtained any amount of formal education (N = 57) reported awareness. Three out of nine individuals who stopped their formal education at senior secondary school and two out of three individuals who obtained university level education reported awareness of zoonosis. However, among individuals who received and did not receive any formal education, there was no significant difference in knowledge of zoonotic transmission (χ^2 = 3.7747, P = 0.0520).

Cultural traits did not appear to influence reported awareness of zoonotic disease transmission potential. There was no difference in reported knowledge of zoonosis among individuals when analyzed by tribe, religion, or gender (by tribe, χ^2 = 2.1640, P = 0.3389; by religion, χ^2 = 1.4613, P = 0.2267; by gender, χ^2 = 0.0795, P = 0.7780). In addition, there was no difference in reported awareness of zoonotic disease transmission between individuals who cut themselves

Table 2. Accidental self-Cutting Frequency Among Hunters and Traders.

Survey question: Do you cut yourself often while handling bushmeat?

	Yes	No	Total
Hunt only	2	30	32
Hunt and trade	5	64	69
Trade only	8	13	21
Total	15	107	122

Degrees of freedom: 2. $\chi^2 = 14.2808$. $P \leq 0.001$. The distribution is significant.

Table 3. Accidental Self-Cutting Frequency Among Men and Women.

Survey question: Do you cut yourself often while handling bushmeat?

	Yes	No	Total
Men	9	95	104
Women	6	13	19
Total	15	108	123

Degrees of freedom: 1. $\chi^2 = 7.8850$. $P \leq 0.01$. The distribution is significant.

frequently and those who did not ($\chi^2 = 3.2411$, $P = 0.0718$). Only one individual of those who cut themselves frequently ($N = 15$) reported awareness of animal-to-human disease transmission.

Frequency of cutting oneself while handling bushmeat varied among individuals who exclusively hunted, hunted and traded, and exclusively traded ($\chi^2 = 14.6902$, $P < 0.05$) (Table 2). Less than 10% of individuals ($N = 10$) who exclusively hunted or both hunted and traded reported to cut themselves regularly. In contrast, 38% ($N = 8$) of individuals who only engaged in trading activity reported to cut themselves on a regular basis. Of all individuals who engaged in some hunting activity, 63% ($N = 64$) reported never having cut themselves. As predicted, percentages of men and women who reported to accidently cut themselves frequently differed significantly ($\chi^2 = 7.8850$, $P < 0.01$) (Table 3). Of those who reported to cut themselves regularly ($N = 15$), nine were female.

Survey participants who reported awareness of zoonosis were asked to list up to three examples of animals and their corresponding disease (Table 4). These animals were reported to transmit diseases to humans via consumption of their bushmeat or through animal bite. While participants listed specific animal species, not all represented an established matching of the diseases to the animal vector. In addition to collecting information on zoonotic disease, I also collected data on the use of wildlife in traditional cures and medicines. Eighteen percent ($N = 22$) of all participants reported that wildlife could serve medicinal purposes when parts of the animal were consumed, worn, or applied to an injured area. Awareness of zoonosis differed among those who believed in wildlife usage in traditional medicine compared to those who did not ($\chi^2 = 8.0672$, $P < 0.01$) (Table 5). Thirty-four percent ($N = 7$) of individuals who reported wildlife to be used in traditional medicine practices reported awareness of zoonosis compared to 12% ($N = 15$) of individuals who did not report usage in traditional medicines.

Discussion

These results suggest important areas of interest for both conservation and public health. The majority of respondents hunted frequently for both subsistence and commercial purposes. Most individuals reported farming as their primary activity, and 77% of these individuals hunted bushmeat for consumption and trade. With almost all respondents reporting hunting and trapping at least once per week, it appears that bushmeat hunting and trading may serve as a means for generating extra income. In a study of a logging camp village in the Congo Basin, Wilkie et al. (1998) determined that hunters could supplement their income through bushmeat to reach levels above minimum wage. In this village, bushmeat sales contributed 6–40% of household daily income.

It does not appear that education level (which could influence income opportunities) affects hunting and trading frequency in Sierra Leone. There was no significant difference in the percentages of individuals who hunted for both consumption and trade when analyzed by amount of formal education obtained. As 68% of hunters reported hunting for both food and trade, bushmeat may serve as a means of obtaining supplemental income for hunters regardless of education level. This finding contrasts with that of LeBreton et al. (2006) who did find a direct relationship between education level and involvement in the bushmeat trade. However, this discrepancy may be

Table 4. Examples of Disease-Giving Animals Listed by Participants (Not Listed in Any Rank Order).

Disease animal	Disease listed by survey participant	Route of transmission
Gambian Pouched Rat (*Crycetomys gambianus)*	Stomach ache, Lassa Fever	Lassa fever has been transmitted by genus *Mastomys* and other species of genus *Crycetomys*, but no reports of transmission by *C. gambianus* (Monath 1975)
Ornate Monitor Lizard (*Varanus ornatus*)	Rash	
Monkey	HIV/AIDS, typhoid fever	Most cases of typhoid fever are water-borne (Bhutta, 2006)
Python (Most likely the African Rock Python, *Python sebae sebae*)	Rash	
Rat (*Rattus rattus*)	Lassa fever	
Gabon Viper (*Bitis gabonica*)	Rash	
Red River Hog (*Potamochoerus porcus*)	Rash	
Wild Fowl	Eczema	Most cases of eczema are due to an Williams autoimmune condition or allergy (Williams and Grindlay 2010)
Common Warthog (*Phacochoerus africanus*)	Rash, typhoid fever	Most cases of typhoid fever are water-borne (Monath 1975)

Table 5. Awareness of zoonotic Disease Transmission and Traditional Medicine.

Survey question: Do you think that animals can transmit diseases to humans?

	Yes	No	Total
Reports that animals can be used in traditional medicine	22	43	65
Does not report that animals can be used in traditional medicine	7	51	58
Total	29	94	123

Degrees of freedom: 1. $\chi^2 = 8.0672$. $P \leq 0.01$. The distribution is significant.

influenced by the small sample size of this study and its focus on hunters and traders only as opposed to a larger sample that included individuals not involved in the bushmeat trade.

Though no endangered animal species was reported as a preferred game species, this result may differ from what has been observed in other countries due to varying hunting methods. In countries such as Cameroon and the Democratic Republic of Congo, endangered primate species including the drill (*Mandrillus leucophaeus*), gorilla (*G. gorilla*), and chimpanzee (*P. troglodytes*) are hunted. In these countries, shotguns are used to hunt bushmeat (de Merode et al. 2004; Willcox and Nambu 2007), and access to guns has increased (Kumpel et al. 2008). Primates and other medium-to-large bodied species are especially vulnerable to hunting by gun (Steel 1994). No participant of this survey reported current gun use for bushmeat hunting. As a result of the Sierra Leone Disarmament, Demobilization, and Reintegration Program, gun ownership among civilians is illegal, and acquisition of guns thus occurs through illegal importation (UNDDR.org). It is possible that survey participants may not have felt comfortable in discussing gun usage due to its illegal nature. However, if gun usage is actually low among hunters in Sierra Leone, hunters are ill-equipped to hunt and target larger or endangered game animals.

According to Bowen-Jones and Pendry (1999), although gun usage allows greater hunting efficiency, it is ultimately demand that drives unsustainable hunting. In addition, Bowen-Jones and Pendry (1999) cite snare usage as a factor influencing overharvesting of bushmeat. Snaring, which is typical of rural hunting (Wildlife Conservation Society 1996), is not species-specific, and can have unintended consequences

Figure 3. Butchering and preparation of bushmeat.

Figure 4. Sale of bushmeat along Bo-Kenema highway.

in capturing larger or endangered species. In this survey, 75% of hunters used wire snares on a regular basis. Thus, they may engage in non-specific hunting and rely on whatever game animal becomes caught in the snare traps. This pattern is reflected in the hunting preferences reported by the majority of hunters. The relatively abundant Greater Cane Rat (*T. swinderianus*), Maxwell's duiker (*P. maxwellii*), and bushbuck (*T. scriptus*) were listed as preferred species, and they can be caught using snare traps. Non-preferred species, like the water buffalo (*S. caffer*), chimpanzee (*P. troglodytes verus*), and warthog (*Phacochoerus africanus*), are larger and either cannot be caught via snares or are capable of damaging snares. Hunters reported the size and danger of hunting these species as reasons why they were not preferred, suggesting that these hunters may not be properly equipped for their capture.

High frequency of hunting represents an increased opportunity to come into contact with disease-carrying animals. Those whose primary role is to prepare and trade bushmeat may be at disproportionate risk. Accidental self-cutting, which is a route of exposure for pathogens, was higher among individuals who exclusively engaged in trading compared to individuals who hunted. As predicted and consistent with previous field studies (Wolfe et al. 2004a, b; LeBreton et al. 2006), women constituted the majority of traders. When viewing traders as an at-risk group for zoonotic disease transmission, it is, therefore, important to acknowledge gender as a potential risk factor. This survey found that women were 23% more likely to cut themselves regularly compared to men. In addition, self-cutting leaves individuals at risk of having open wounds where bloodborne pathogens can enter (Fig. 3).

In addition, women were more likely to serve at the higher end of the bushmeat commodity chain, where they buy bushmeat from rural hunters and transport it elsewhere, either to other villages, or larger market towns or cities (Bowen-Jones et al. 2003) (Fig. 4). Although most individuals in this study restricted bushmeat trading to their own village, this is not necessarily representative of bushmeat trading in other locations. In a study of the urban Ga district in Ghana, King et al. (2000) reported that women are an integral part of the informal food industry—they operate "chop bars," or stands, which can prepare and sell bushmeat-based meals. As women may travel in the act of trading bushmeat, pathogens have an opportunity to travel beyond the origin of transmission.

While risk factors for zoonotic disease transmission (i.e., high frequency of contact with bushmeat animals and accidental cutting) were observed among hunters and traders, only 24% of participants reported awareness of zoonosis. There was no observable trend between hunting frequency and reported awareness of zoonotic potential, as the majority hunted at least once per week. In addition, amount of formal education obtained was not associated with awareness of zoonosis. There were no differences in reported awareness among different tribes, religions, or genders. However, there remains a possibility that traditional knowledge of disease and medicine could influence perceptions of zoonosis. When individuals who reported awareness of animal-to-human disease transmission were asked to provide examples, they provided animal/disease relationships that were not based on confirmed routes of transmission. For example, individuals stated that consumption of monkeys and warthogs results in Typhoid

fever and interaction with wild fowl yields eczema. These could be examples of cultural notions of animals' roles in human disease and health. In addition to playing a role in human disease, wildlife can play a role in traditional medicines. Eighteen percent of all participants reported that wildlife could be used in traditional medicine. Individuals who reported use of animal-based traditional medicines were 22% more likely to report awareness of animal-to-human disease transmission. For these individuals, wildlife may play a very important role in traditional notions of human health and disease, indicating cultural influence in their perception of animal-to-human transmission. Understanding traditional views on disease and healing is important not only to understand the impact it may have on conservation efforts, but also to design more culturally-sensitive and effective conservation tools.

This paper is the only study to date which attempted to measure zoonotic disease risk awareness among bushmeat hunters and traders prior to an education intervention. As this is a preliminary study of a relatively small group of bushmeat hunters and traders, future steps should include gauging zoonotic disease awareness on a larger scale. However, limitations to the current study must first be addressed. First, the sample size of the study was small, leaving the study underpowered and precluding determination of several statistically significant relationships. With more participants, a more representative sample can be obtained, and a more accurate relationship between education level, zoonotic disease awareness, and risk can be gauged. In addition, convenience sampling methods could have introduced bias into results. Tacugama staff conducted interviews, and thus participants may have felt influenced to underreport their involvement in bushmeat hunting or trading, or alter responses related to which animals were preferred game species. Although Sanctuary staff explained to village chieftains and all participants of the survey that results were only to be used for research purposes, participants still may have felt the need to censor their responses. No individual reported use of guns or preference for chimpanzees. Only one individual in this study outwardly expressed knowledge that hunting chimpanzees was illegal. Steel (1994) reported that market vendors' knowledge of the illegal nature of hunting apes could result in underreporting ape hunting. These limitations should be kept in mind in the consideration of the trends reported in this paper.

This study provides information that is useful for the design of a public health education model if one is to be implemented. Although there was no finding that formal education was associated with increased awareness, this does not suggest that individuals would not be receptive to an education program. Currently, public health education models for bushmeat hunters have not been widely incorporated into conservation education programs or into community-based conservation in general, and so their success has not been determined. While a public health education program may be useful to aid conservation efforts, it cannot operate in isolation. As evidenced in previous findings and suggested by this study, bushmeat may provide not just a vital source of protein, but also income. It would be ineffective, and arguably unethical, to expect communities to reduce bushmeat hunting without providing alternative means of food sources and income. In addition, much of the reported hunting appears to be of non-endangered species. Thus, it may be useful to stress reduction of hunting of protected species where possible, while promoting sustainable hunting of non-endangered species and safe butchering practices. This could include snare-use minimization strategies suggested by Bowen-Jones and Pendry (1999) that reduce the chances of accidentally trapping protected species. As much of this country is resource poor, it may be useful to provide options for additional income-generating activities in addition to implementing an education campaign. Small-scale animal husbandry, apiculture, and agricultural development projects may prove feasible in this region of Western Africa. Currently, the Tacugama Chimpanzee Sanctuary is initiating pilot programs to aid villages located near chimpanzee-populated areas with agricultural kits in exchange for their service as stewards of the surrounding protected wildlife. If education and development programs are effectively instituted in tandem, they may help achieve conservation goals.

In the development of such an education program, it is of utmost importance that all educational materials are presented in a culturally sensitive manner. Obtaining support from community leaders and health officials will be necessary for finding effective ways in which to connect with the communities receiving a public health education model. Collaboration among experts in conservation, public health, and community education will be necessary to increase awareness of zoonotic transmission among those most vulnerable.

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